Breakdown Characterization in 805 MHz Cavities in Strong Magnetic Fields

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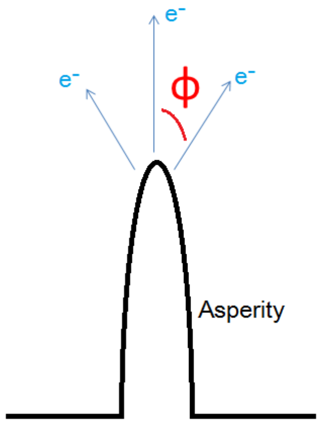
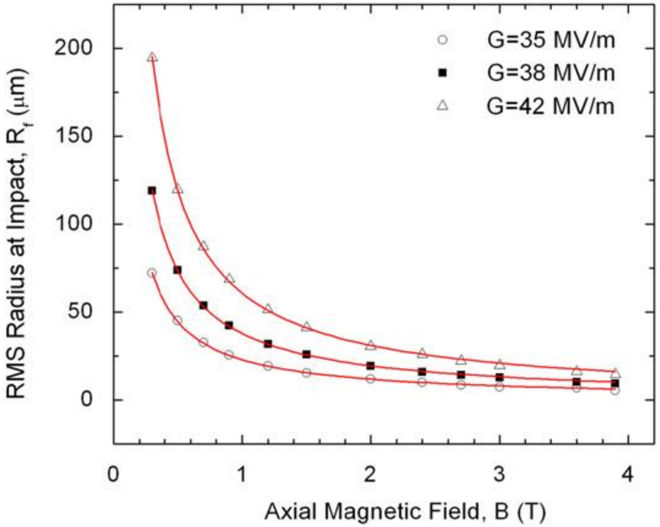
Problem of RF breakdown

- BD limits performance of accelerator cavities
- BD rate goes up in strong static magnetic fields
  - Required in ionization cooling designs
  - Applications include RF gun design, tokamak conditioning, klystron lifetime studies etc.
- Current “allowed” spark rate is 10^{-5}

Model of a breakdown in strong B fields

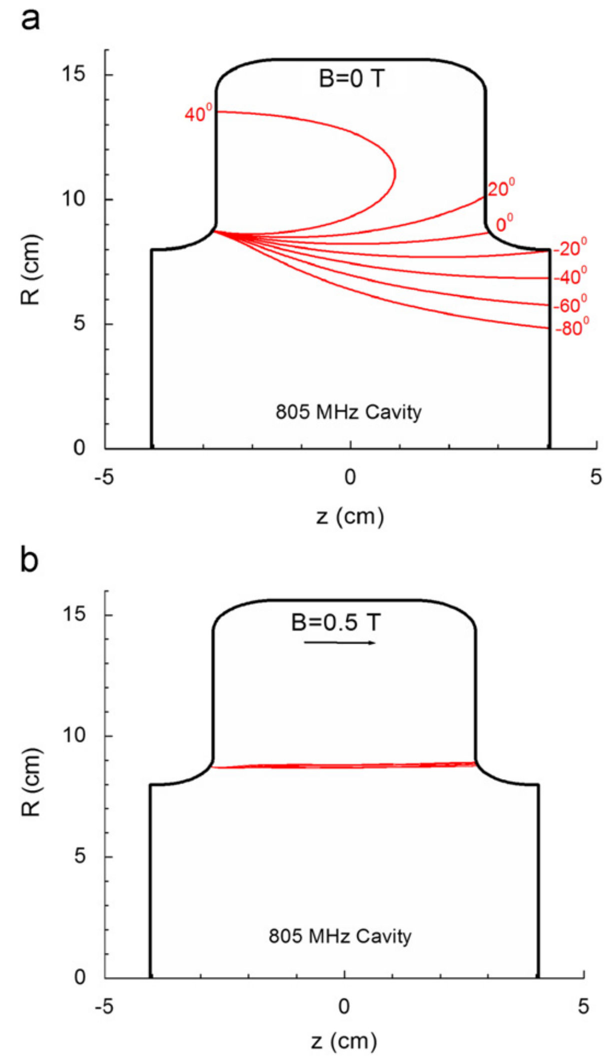


- Electron field emission from surface imperfections
- B field focuses dark current into beamlets
- Beamlets cause pulsed heating -> damage



Potential mitigations:

- Surface treatment
- Use higher radiation length materials (Be)
- Decrease impact energy of electrons
  - Longer RF gap
  - Change B || E configuration

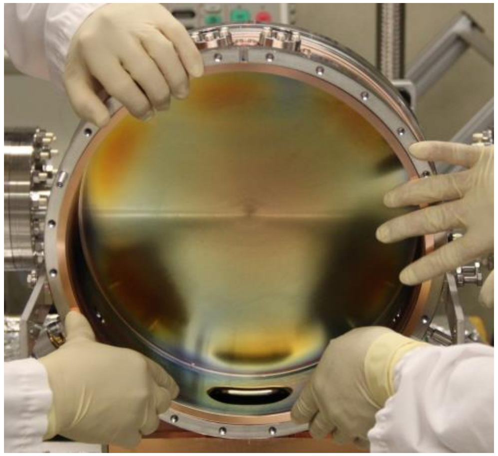


D.Stratakis , J.Gallardo, R.Palmer, Nucl. Inst. Meth. A 620 (2010), 147-154

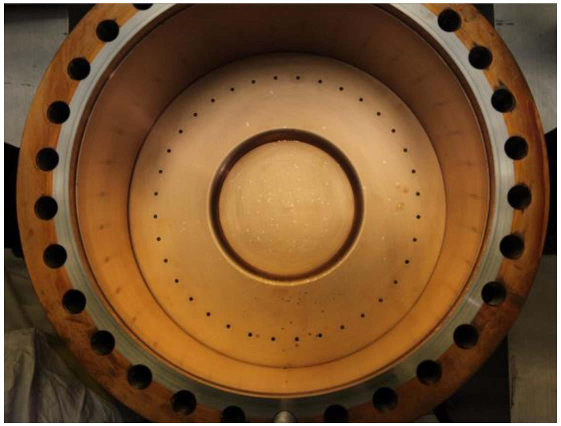
Mitigation technique: surface treatment

201 MHz MICE cavity - electro polished, clean room environment Conditioned to design gradient with no breakdowns so far.

Modular Cavity - chemically polished, clean room environment. 0 Tesla run look promising

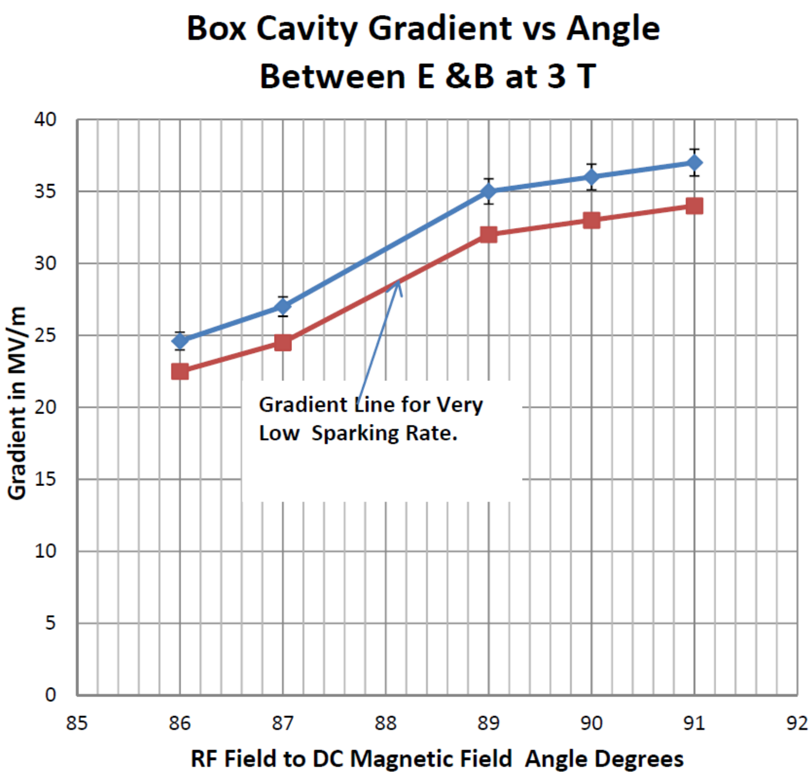


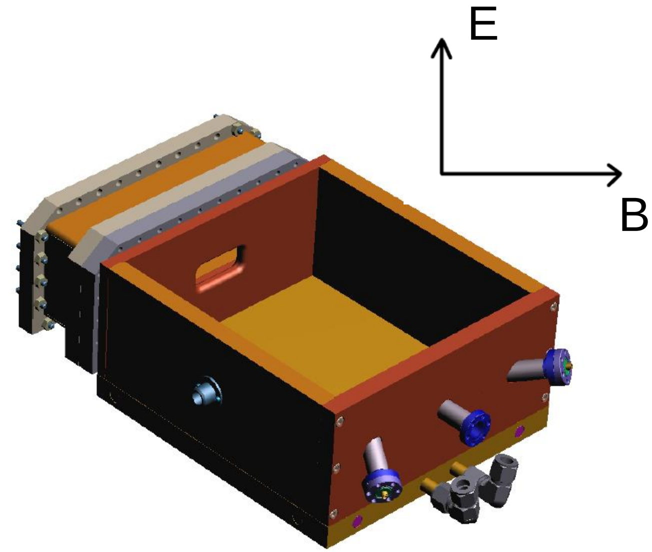
All Seasons Cavity – stainless steel with copper coating



Mitigation technique: geometry

- Box cavity: magnetic insulation



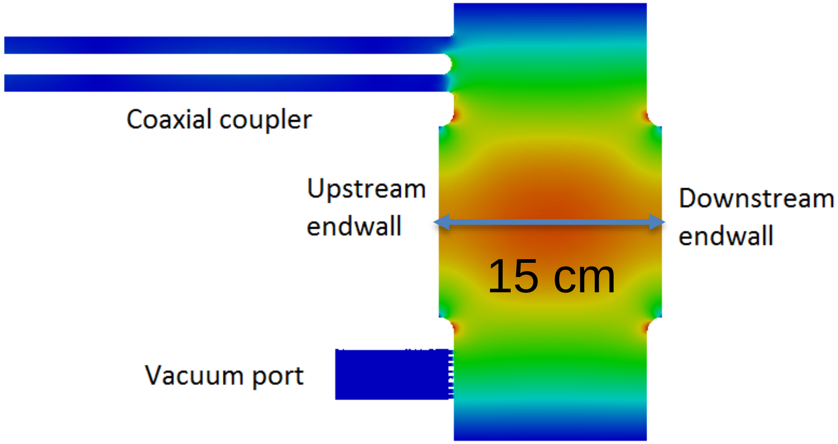


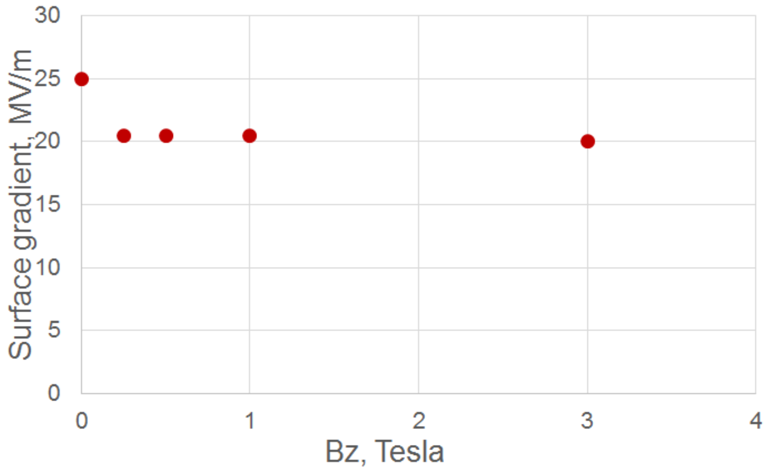
Magnetic field deflects dark current electrons to low E field regions

Works well only for angles very close to 90^o
Small shunt impedance compared to pillbox cavities

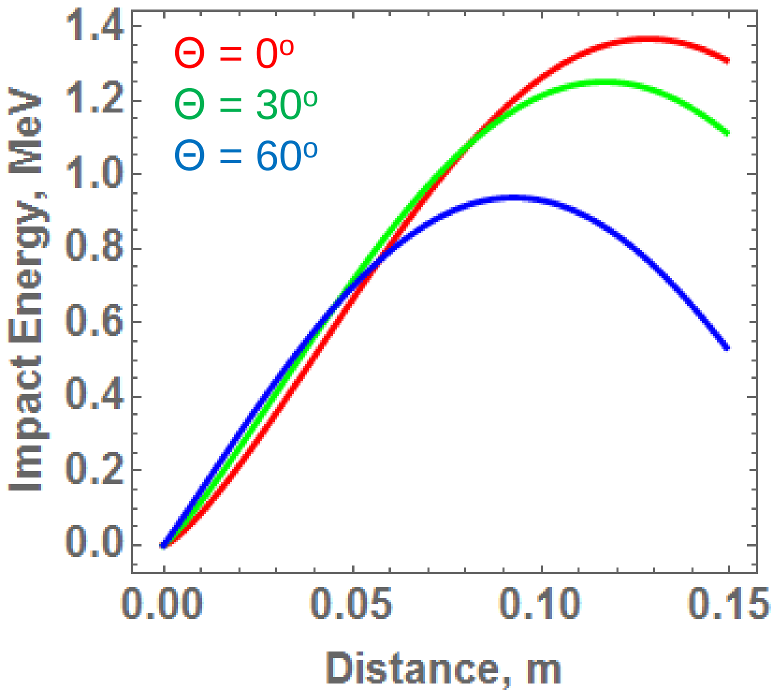
Mitigation technique: geometry

All Seasons Cavity: longer RF gap length





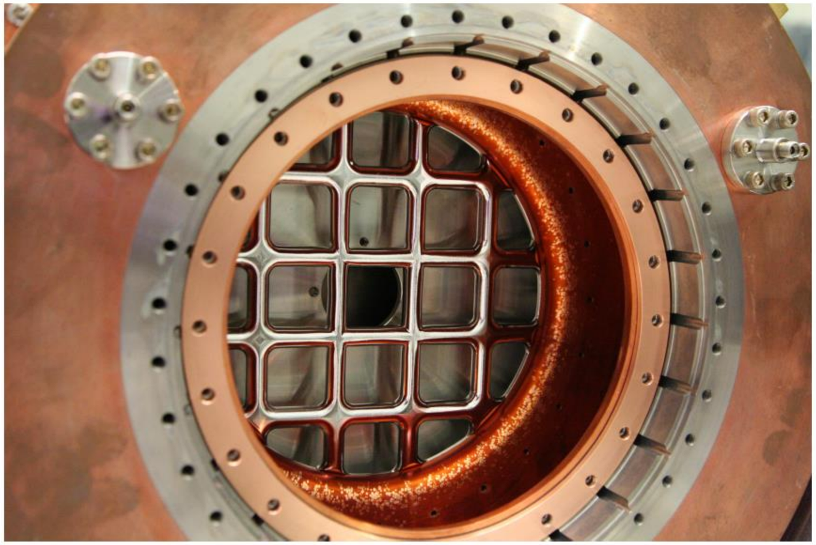
Electron energy as a function of cavity length

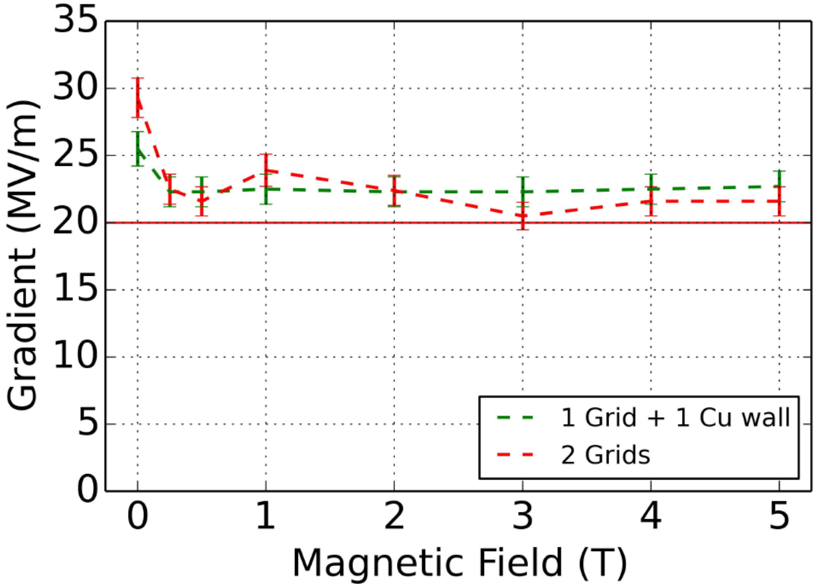


Mitigation Technique: geometry

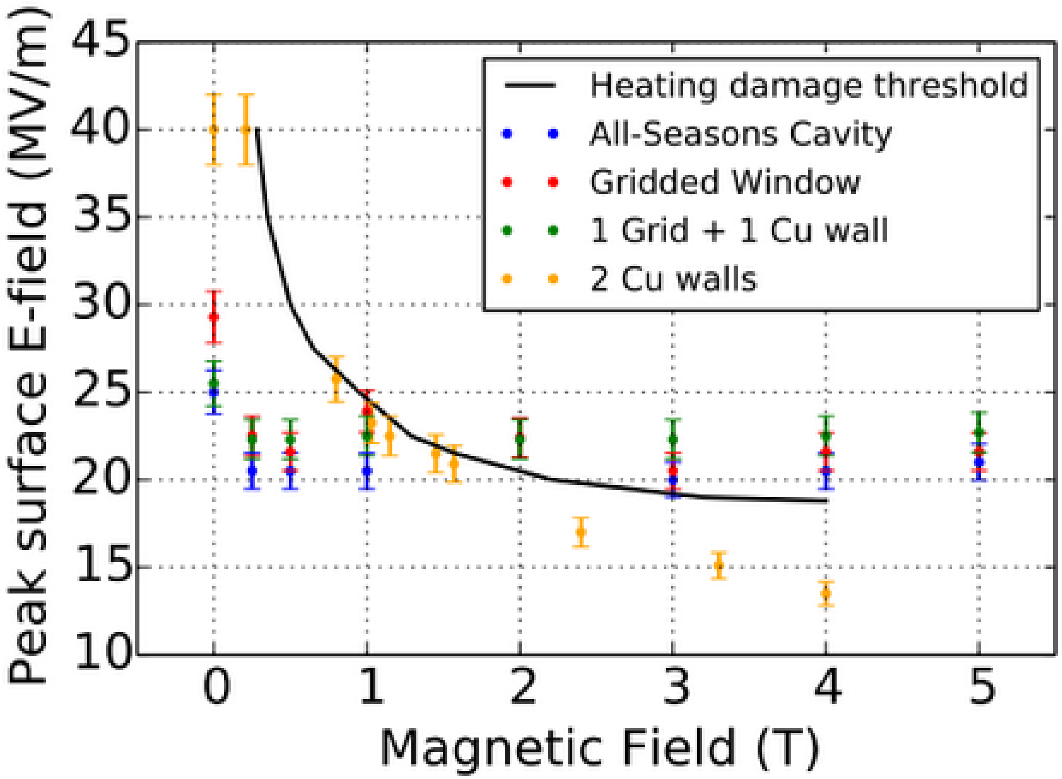
Grid windows

- Allow the beam to pass though
- Increase shunt impedance of the cavity
- Allow dark current beamlets to exit cavity volume





Results



Factors that may affect the fit quality:

- Condition history
- Local field enhancement around coupler regions
- Surface treatment

Data acquisition and run control system

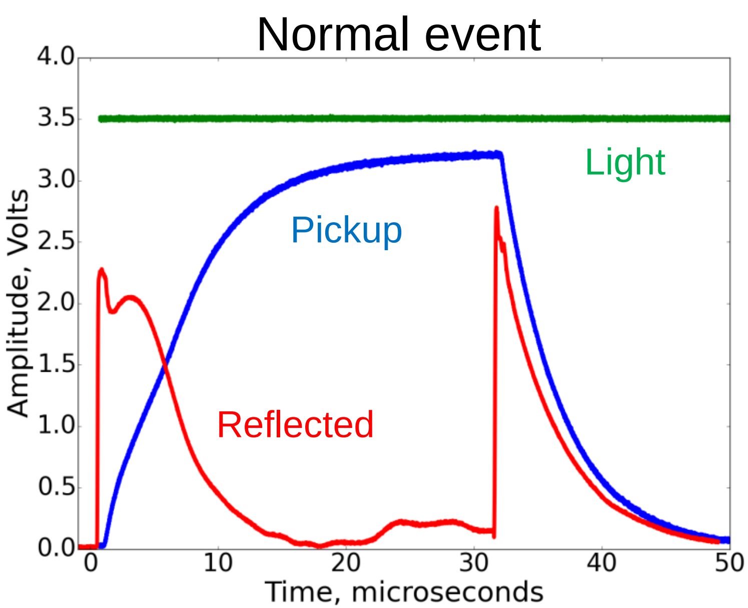
- Was recently upgraded, effort lead by B.Freemire
- Fast oscilloscopes to record time sensitive signals   <- Labview
  - Cavity pickups
  - Light signal from optical fibers
  - Scintillators (X ray detection)
  - Forward and reflected power
- Vacuum pressure data
- Temperature sensors
- Light spectrometry
- Spark acoustic localization

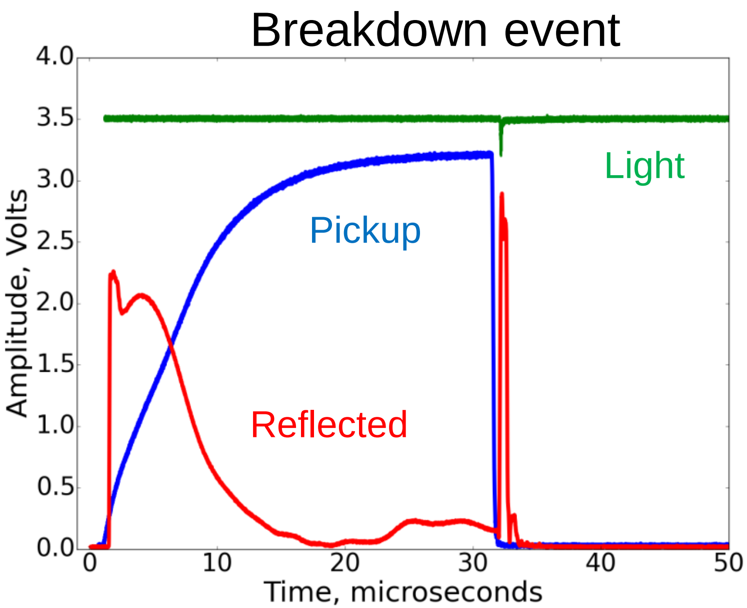
Spark detection

Labview monitors waveforms, keeps the log, triggers on sparks

Automated system for spark detection (by D.Peterson)

- Abrupt drop in pickup voltage OR
- Flesh of light from optical port OR
- Spike in reflected power

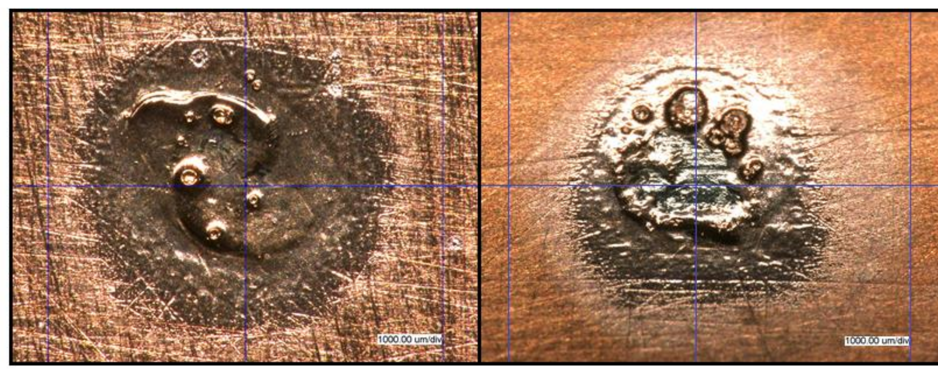




Damage inspection

Cabinet is designed to operate in a portable clean room.

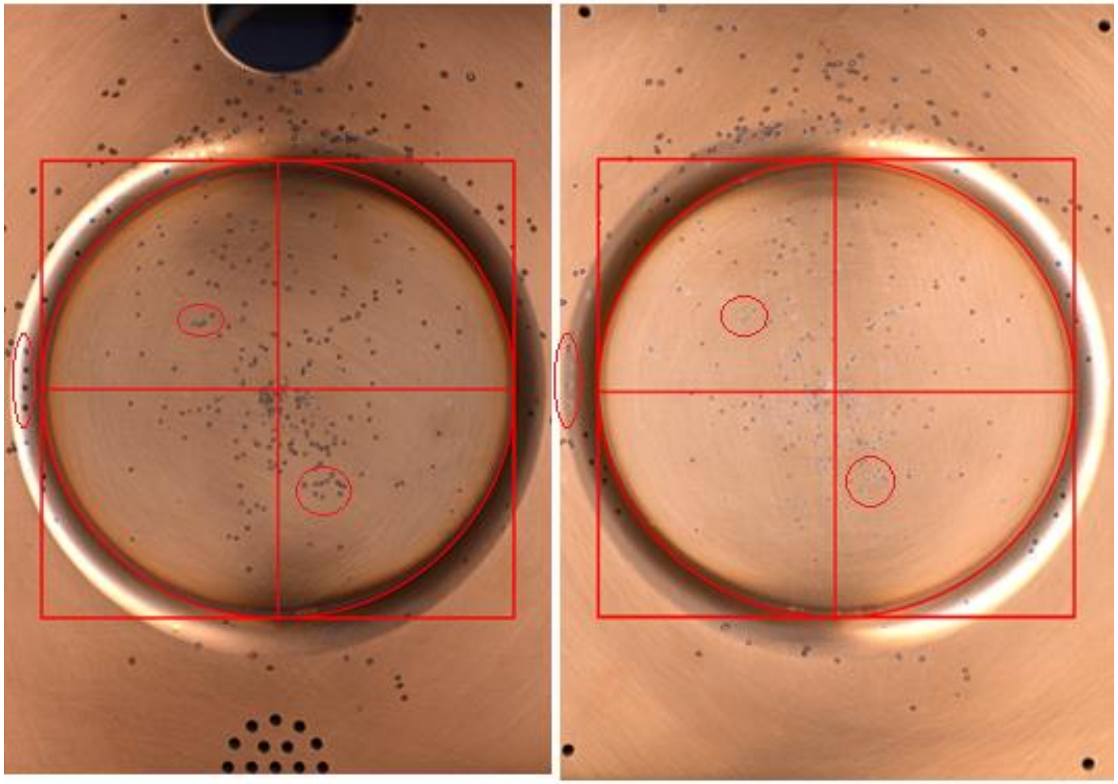
- Flatbed scanner with 10^5 pixels per mm^2
- Digital VHX-100K microscope with 3D imaging capabilities.



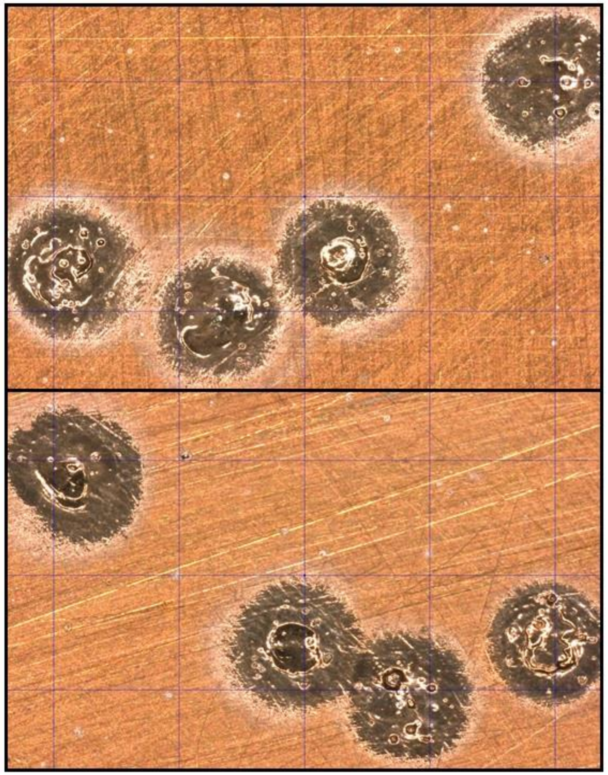
Typical close-up of damage site.
Diameter of the pit ~ 1mm

Damage characterization

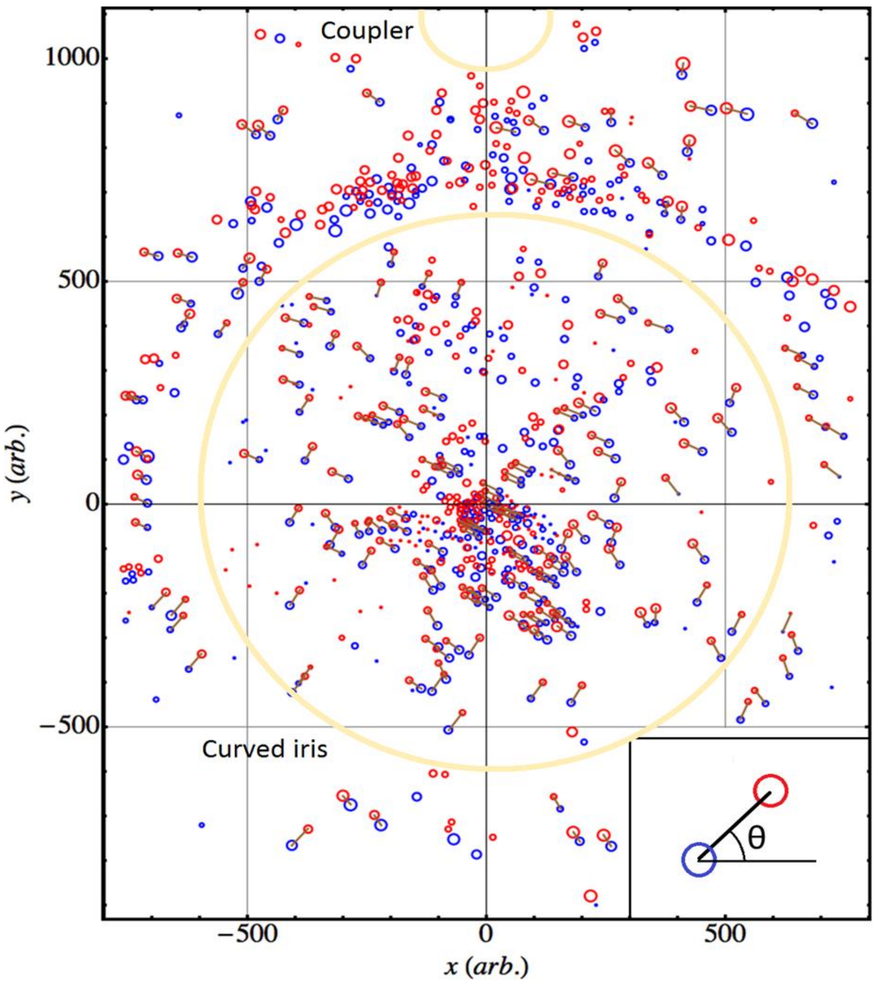
Scanned image of two end plates



Example of a pattern

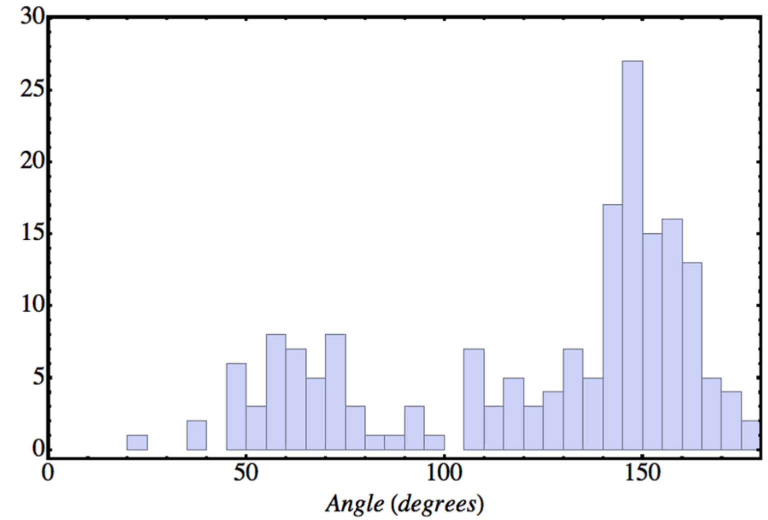


Damage characterization

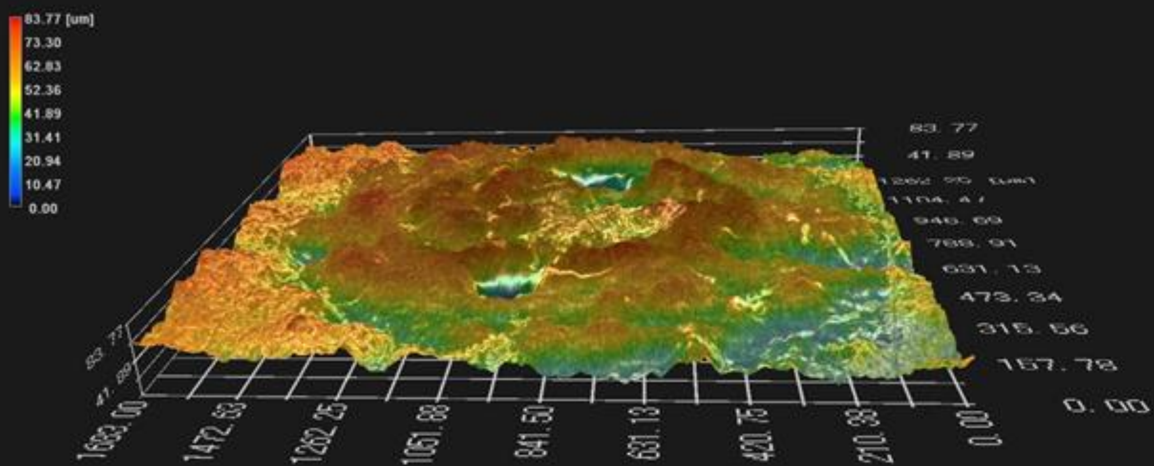


- Pattern recognition script
- Accumulated ~ 200 sparks on each endplate
- BD pit distribution follows field enhanced regions
- One-to-One pit correspondence

Histogram of pit orientations

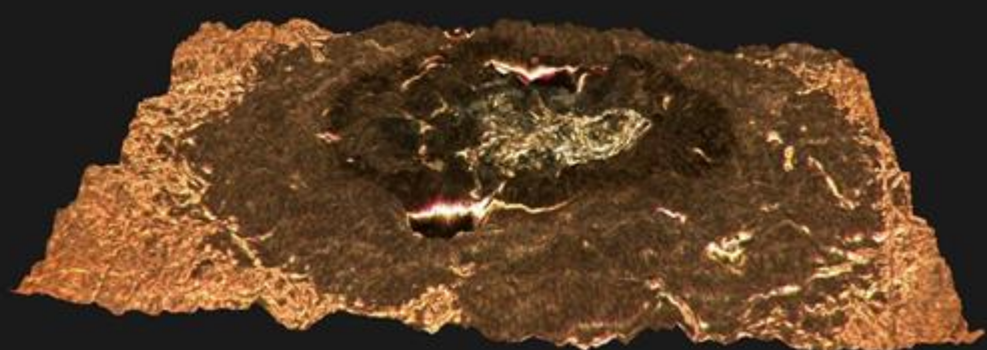


Estimation of deposited energy



Depth From Defocus (D.F.D.) to construct 3d model

Estimate deposited energy by amount of melted material



Energy needed to melt 2 similar pit volumes of copper: ~ 1 Joules

Energy stored in a cavity at 20MV/m : ~ 4 Joules

Surface roughening from BD may induce future sparks -> material lifetime study

Conclusions

- We demonstrated 20MV/m performance in several 805 MHz cavities in external magnetic fields up to 5T
- Our experimental findings in general agree with our model of breakdown in strong magnetic fields
- We have a run control / DAQ system that allows us to study BD phenomenon in great detail
- More systematic study is needed. Current MC program at MTA addresses this issue